Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

Issued November 8, 1912.

U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—BULLETIN 113.

HENRY S. GRAVES, Forester.

METHODS AND APPARATUS FOR THE PREVENTION AND CONTROL OF FOREST FIRES,

AS EXEMPLIFIED ON THE ARKANSAS NATIONAL FOREST.

BY

DANIEL W. ADAMS,

FOREST EXAMINER.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1912.

USING THE HORSE PACK-WATER-BAG AND FIRE SHIELD TO FIGHT A SURFACE FIRE WHERE THERE IS BUT LITTLE WIND.
SEE PAGE 17.

Issued November 8, 1912.

U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—BULLETIN 113.

HENRY S. GRAVES, Forester.

METHODS AND APPARATUS FOR THE PREVENTION AND CONTROL OF FOREST FIRES,

AS EXEMPLIFIED ON THE ARKANSAS NATIONAL FOREST.

BY

DANIEL W. ADAMS,

FOREST EXAMINER.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1912.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., June 20, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "Methods and Apparatus for the Prevention and Control of Forest Fires, as Exemplified on the Arkansas National Forest," by Daniel W. Adams, Forest Examiner, and to recommend its publication as Bulletin 113 of the Forest Service.

Respectfully,

Henry S. Graves,
Forester.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

	Page.
Losses from fire	5
The fire situation in the Arkansas National Forest	6
Problems which confronted the Forest Service	7
Methods of fire prevention	7
Educative efforts	7
Forest Fire Protective Association	7
Measures for fire protection	8
Old methods inadequate	8
Difficulties in locating fires	9
Range-finding lookout towers	10
Construction and cost	10
The range finder	11
Fire-plan maps	12
Modified form of range finder	13
Methods of fire fighting	14
Direct attack	15
Lines of defense	15
Special apparatus	16
Water bags and tanks	17
Fire shields	17
Chemical extinguishers	18
Railway fire engines	18
Tests of the towers and apparatus	22
Saving due to improved methods	22
A new system of logging and fire lines	23

ILLUSTRATIONS.

PLATES.

Page.

PLATE I. Using the horse-pack water bag and fire shield to fight a surface fire ..... Frontispiece.
II. Range-finder signal tower No. 2 12
III. Fig. 1.—Beating out a fire with green boughs. Fig. 2.—Fire-fighting crew 16
IV. Fig. 1.—Forest officer signaling with lanterns. Fig. 2.—Forest officer with complete fire-fighting outfit. Fig. 3.—"Fire-engine house" at Womble, Ark 16
V. Fig. 1.—Water-pressure tanks. Fig. 2.—Forest officer using shoulder pack, water bag, and fire shield 16
VI. Chemical apparatus for use on horseback 16

TEXT FIGURES.

FIG. 1. Fire-plan map 12
2. Chemical apparatus for shoulder use 16
3. Side view of gasoline-propelled fire-fighting engine 19
4. End view of railroad fire engine 20
5. Trailer for railroad fire engine 21
6. Typical lumbering area 24
7. New location for fire lines 25
8. Effect of the new location for fire lines 26

METHODS AND APPARATUS FOR THE PREVENTION AND CONTROL OF FOREST FIRES, AS EXEMPLIFIED ON THE ARKANSAS NATIONAL FOREST.

LOSSES FROM FIRE.

While the seriousness of forest fires is generally known and conceded,[1] it is not realized that losses, including those of forest products and young timber, are far in excess of the annual consumption of timber for commercial uses. This loss becomes more apparent with the realization that the total fire damage includes not only the material that is consumed at the time of the conflagration, but that which may follow through years of deterioration and decay of timber which was not actually destroyed at the time the original injury was inflicted. This subsequent deterioration is particularly true of hardwood species that are susceptible to fungous diseases and insect infestation. Fortunately, most of the conifers that survive a fire cover the wound with a layer of pitch which is supplemented by an accumulation of resinous wood within the trunk and near the exposed surface. This pitch will usually, but not always, prevent insect attack. It has, however, the effect of rendering that portion of the tree which should be the most valuable unfit for merchantable uses, because of the "pitch pockets" which are exposed during the process of manufacture. Conifers without enough resin thus to resist insect injury are likely to succumb to the infestation or to decay which shortly follows the insects. Further, this accumulation of pitch in fire wounds frequently results in the complete destruction of the tree by succeeding fires, which feed upon the pitch of the exposed surface.

The young seedling and coppice growth in a lumbered forest is particularly susceptible to fire injury, and if it is not killed outright the lumber subsequently manufactured from these trees is materially reduced in grade.

Another loss, second only to the actual damage to the timber, and, in some localities, even greater than the timber loss, is the destruction of the forest floor of decaying vegetation, which would make

[1] For other Forest Service publications on the subject of forest fires see Bulletin 82, Protection of Forests from Fire; Circular 205, Forest Fire Protection Under the Weeks Law in Cooperation with the States; Yearbook Separate 548, Fire Prevention and Control on the National Forests.

humus to protect the surface and sustain tree growth. It has been found, even in the best protected and most heavily wooded regions, that the loss from fires includes not only the burned timber and the surface layer of vegetable matter, but the rich topsoil which has resulted from the decay of litter previously accumulated. This is left exposed and is soon washed away.

The Government's large expenditures for the acquisition of lands in the Southern Appalachian and White Mountain regions for the protection of navigable streams can not successfully attain their object unless forest fire is prevented and controlled.

THE FIRE SITUATION ON THE ARKANSAS NATIONAL FOREST.

The timber region covered by the Arkansas National Forest in the State of Arkansas presents conditions almost identical with those of the Southern Appalachians, with the possible exception that the woods burning had become more a fixed habit in the Arkansas Forest region. There are a number local causes which contribute to this; and, as with a great many established customs of primitive peoples, the arguments advanced in favor of burning were found, upon investigation, to be fallacious. The earlier settlers burned the woods to facilitate hunting and, according to their claims, to exterminate ticks and other insects, as well as to drive out the snakes which at one time infested the country. The succeeding generations maintained the same practice of annual burnings, claiming that these would improve the range and prevent stock diseases.

Later, when the country became more populated, a spirit of lawlessness arose among a few, who felt that the new conditions were burdensome. A great many fires were set to burn the fences away from pasture lands and from cultivated fields, so that the stock of these irresponsible persons might profit by the exposed condition of the grasses and crops. The ultimate result of several generations of those who practiced this sort of thing was that the timber stands were depleted; there was an almost total lack of young timber and a sadly deteriorated mature stand. More serious than this was the resultant sterile and barren condition of the woodland upon which the farmer depended for future farming industries. His first cleared lands had early become too badly worn out for cultivation, through the crude agricultural standards which had prevailed.

Another evil result was the filling up of the woodland with a scrub growth of coppice which had stooled out from successive burnings into numerous sprouts. These so divided the strength of the original root that in many instances good merchantable stands were reduced to brush land.

The run-off was so rapid in this burned-over area that shortly after a rainy season the streams dropped down so low that water

was not always procurable for stock. In many instances the springs went dry and the soil was parched and baked by exposure to the sun; and this in a region in which nature had provided a heavy forest and vegetative cover.

PROBLEMS WHICH CONFRONTED THE FOREST SERVICE.

These conditions confronted the officers of the Arkansas National Forest when it was put under administration in 1908. While they were discouraging, they presented an especially favorable field for testing the efficiency of methods and devices which had been the subject of long and specialized study.

METHODS OF FIRE PREVENTION.

The first step was to determine the best way to mold popular sentiment so that the people would change from the attitude which favored, or at least passively tolerated, forest fires to one which would make them enthusiastic for fire prevention and control. The second step was to adopt mechanical means of fire fighting which would be more effectual than the methods commonly in use.

EDUCATIVE EFFORTS.

The initial move for a changed sentiment toward forest fires was the organization of the Mutual Forest Fire Protective Association by the citizens of Arkansas in cooperation with the Forest Service. Prominent men were interested, and from their number a president, vice president, board of directors, and treasurer were elected. Later, with the approval of the Secretary of Agriculture, a member of the Forest Service was elected as secretary. This member, in cooperation with the supervisor, pushed the organization and membership to where the finances, derived from a small annual membership fee and liberal cash donations by those who would benefit most from fire protection, permitted the offering of rewards for the apprehension of persons setting fire to the woods.

FOREST FIRE PROTECTIVE ASSOCIATION.

The object of the association is the suppression of forest fires on and near the Ozark and Arkansas National Forests. It enjoins upon its members the following duties: To report immediately any forest fire to the nearest forest officer; to assist in fire fighting and to secure the services of others; to create a vigorous sentiment against setting fire to the woods; and to aid in the detection and conviction of those who set fires.

The association has a standing offer of a reward of $50 to persons furnishing evidence which results in the conviction of anyone who

sets fire to woodlands owned by the Government or by members of the association. The notice of reward is here given:

$50 REWARD.

This property is protected by a reward of Fifty Dollars, to be paid by the Mutual Forest Fire Protective Association, for information that will lead to the arrest and conviction of any person who sets fire to this woodland, or who sets a fire on other property which spreads and reaches this woodland.

All information and name of informant will be treated as strictly confidential.

Payment of reward will be made promptly upon conviction.

Mutual Forest Fire Protective Association.

The association's efforts, and the distribution of literature on fires and fire fighting, together with the help of the newspapers, resulted in a marked change of public sentiment in regard to woods burning. An incipient opposition to the Forest Service was changed to favorable sentiment as soon as it was seen that the Service was allied intimately with the interests of the people.

MEASURES FOR FIRE PROTECTION.

However; no amount of cooperation and diligence could wholly prevent those forest fires which arise principally from the following causes: (1) Sparks from coal-burning locomotives under forced draft on heavy grades; (2) carelessness of camping parties and hunters; (3) accidental escape of fire from farmers' clearings; (4) incendiary acts of irresponsible persons not amenable to the law or to the influences of public sentiment; and (5) lightning.

To insure successful fire protection and control, even with a good public sentiment, four measures are essential: (1) To ascertain accurately the location of the fire before it has had time to make headway; (2) to secure an effective method of extinguishing it; (3) to devise an economical and safe fire extinguisher; (4) to fell all dead timber on lumbered areas and as much of it as possible in the open forest, since dead trees are most likely to be ignited by lightning.

OLD METHODS INADEQUATE.

It was found that the most energetic use of the old, ordinary method of fire fighting was entirely inadequate to cope with the rapidly burning surface fires, driven by high winds in a broadleaf cover. The undergrowth is largely coppice oaks, whose leaves persist through winter and spring, and make a fierce, hot fire.

In the first place it was ascertained that the usual system of patrol would not do. As in all mountain countries, the roads and trails follow the lines of least resistance, which means that they follow watercourses between mountains on either side, which obstruct and limit the view, so that patrolmen can see only a very short distance.

It was found further that occasional visits by the guards to a mountain top were not sufficient, since the fire risk is constant during the dry season. Moreover, there was no check on the men's trips to the mountain top, nor the duration of their stay at lookout points. Experience on this and other forests has proved that even when smoke is sighted from a mountain top, both its location and distance are largely matters of guess. A guard who saw a formidable-looking smoke would make a long, hard ride, at much cost and inconvenience, only to find that the smoke was caused by some farmer clearing his own land.

Furthermore, no matter how familiar a fire guard might be with the surrounding country, this familiarity did not suffice to give an exact location or, in many cases, even an approximate location of fire. This is because of his inability to differentiate between the location of farmers' clearings and the open forest.

DIFFICULTIES IN LOCATING FIRES.

These conditions point to the need of some device which will give an exact location. It proved to be practically useless to try to locate fire without instrumental aid, because of the hazy or smoky condition of the atmosphere during the fire season, and even quite a formidable fire at first merely tends to increase the smokiness at some particular point and is by no means definitely confined to a recognized area. But if instrumental readings from one station could be correlated with a cross-reading from a corresponding station it could be determined immediately whether thicker smoke is the result of a fire on forest land. Another baffling condition which calls for instrumental aid is the length to which the smoke is drawn out by the prevailing winds. It is quite obvious that if the line of smoke blows directly toward the watchman, or even at an acute angle from or to his line of sight, then the head of the fire might be several miles from its apparent location. This error, of course, can be corrected by instrumental cross-reading from a corresponding station.

Furthermore, forest fires, like those of a city, do not permit of trips of exploration to determine their location and origin. Plans must be quickly and intelligently made for immediate action, because hasty and ill-advised plans of attack are not only expensive but inefficient. It was easy enough to anticipate the probable future location of fires by a study of previous fires and an inquiry into their origin. Through such a study it is possible to place fire-fighting tools and equipment so that they may be readily available. Likewise localities where incendiary or accidental fires are frequent could properly be designated danger zones and so mapped.

RANGE-FINDING LOOKOUT TOWERS.

But these precautions did not take care of fires which would start in communities remote from the danger zones. The inability to locate them by a special danger-zone patrol system suggested the erection of lookout and signal stations on the highest peaks, 10 to 15 miles apart, to locate incipient fires definitely, no matter where they might be. To do this it became necessary to devise and construct a mechanical range finder, since previous experience proved that the use of compass and protractor and the more complicated range-finder equipment introduce innumerable instrumental errors, due to the unskilled labor available and to the hurry and excitement incident to discovery of fire.

It is, of course, true that skilled surveyors or men familiar with the use of scientific instruments would overcome these inaccuracies. But the cost of highly trained men and the difficulty of securing them made their employment an impossibility.

CONSTRUCTION AND COST.

The cost of material and erection of five wooden towers, including construction of roads and pack trails, stub telephone line, and equipment, was $2,100, or an average of $420 each. The net cost of towers and range-finding device alone was not over $300 each. Iron towers 40 feet high can be erected at $400 each.

The tower proper has an addition 12 by 12 feet, which may be constructed in the form of a lean-to for living quarters for the fire guard, who is required to remain in the tower day and night during the fire season. It was possible in most cases to employ men with small families for the lookout work. The bottom of the tower, which is also 12 by 12 feet, afforded another room for their use.

The various towers were from 20 to 30 feet high, according to the topographical conditions on the mountain tops. In the long run, steel structures would be more economical, and, indeed, there is not a great difference in first cost. However, in this connection it is well to consider carefully the danger from electrical storms, which would be greatly increased by the use of steel, a danger likely to be much magnified in the minds of the class of people who could be employed as temporary fireguards.

The roof of the wooden tower is a truncated pyramid and of the iron tower a truncated cone, to furnish a flat upper deck approximately 5 feet square. This deck is rain proof and made accessible by a hatchway 18 by 24 inches. A movable ladder leads from the second story to this opening.

In the center of the superstructure a 25-foot revolving signal mast is erected, with cross arm and halyards for lowering and raising

lanterns, the different positions of which constitute a series of predetermined signals. If this mast is made of iron pipe, a rod may be extended through it, upon which is mounted a vane which registers on a dial over the watchman's head in the cupola below. The dial is laid off and oriented to conform to the points of the compass, so that he may determine, when a fire is sighted, the bearing of the prevailing wind.

The direction and velocity of the prevailing winds should never be overlooked in the hurried plans which follow the sighting and location of a forest fire. Too much haste must never be made. There is an old Arabic adage that if the house is on fire and there are but three minutes in which to save the contents, two should be employed in planning what to do. However, all plans should be made in advance, so far as possible. In actual practice, while it is of the utmost importance to locate a fire quickly, coolness and judgment must be used in the attack if any degree of success is to be attained.

THE RANGE FINDER.

In the second story or cupola of the lookout station there is a sighting hood made with vertical wires 2½° apart, set around the outer circumference. These wires are numbered clockwise from 1 at the north, toward the east, clear around to 144, which gives the 360° of the circle, divided by 144 wires spaced to correspond to the deflection of 2½° each. The wires are 20 gauge, tightly drawn. It was found necessary to use thumb nuts threaded on larger wires, to which the small wires were spliced, so that they could be kept taut under varying atmospheric conditions.

In the exact center of the sighting hood a self-winding plumb bob is suspended; this is drawn down when a fire is sighted and the number of the wire in line between the plumb line and the smoke is noted.

These signal stations are connected both by telephone and signal apparatus; if one should be out of commission, the other can be used. The guard who first sights the fire asks the next nearest signal station for the number of the wire in line with the smoke from his tower. Then by glancing at a map upon which the lines from the wires are projected each guard would instantly note the exact location of the fire by following the numbered lines to their intersection. The lines correspond to the lines of sight through the plumb line to the circle of vertical wires in the sighting hoods. The accompanying map (fig. 1) of the south half of the Arkansas Forest illustrates the method.

It was found necessary to equip the sighting hood with a high-back swivel chair, somewhat of the nature of a box with an open side.

This boxlike chair protects the watchman from wind and weather, affords a shelter for maps at his right and a place to secure a telephone at his left.

FIRE-PLAN MAPS.

Three maps of his contiguous lookout areas are necessary for each watchman. The first map contains merely the land-office subdivisions, with the signal stations platted accurately theron, and the radial lines projected to the margins and numbered there for each station. This map is used to ascertain the exact location of the fire by township, section, and minor subdivision. Reference is then

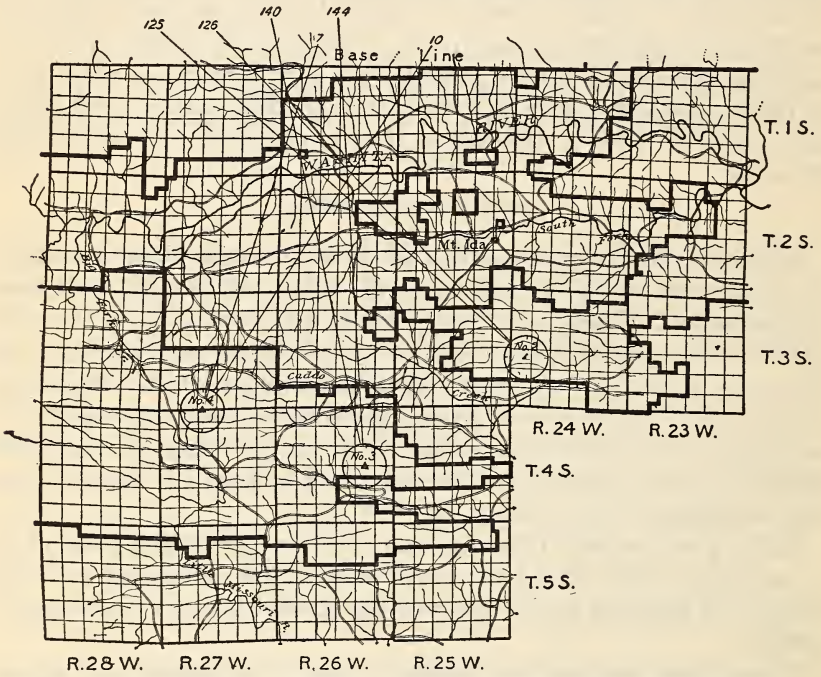


FIG. 1.—Fire-plan map of the southern part of the Arkansas National Forest, showing location of lookout stations and methods of using intersecting lines of sight.

made to the second map, which shows in color the National Forest areas and interior alienations. It enables the officer to determine whether the fire is on forest land, and also what is its relative need for protection.

It is, of course, absolutely necessary that the foundations for the range-finder signal towers shall be oriented to conform to the land-office surveys of the area to be protected. In the event the stations are located in an unsurveyed country a reconnaissance triangulation survey will be facilitated by use of the stations for turning points.

Reference is then made to a supplementary third map, which gives topographic features, including streams, roads, fire lines, trails. water

RANGE-FINDER SIGNAL TOWER NO. 2 ON THE ARKANSAS NATIONAL FOREST.

[Forest officer signaling 20 miles by heliograph.]

holes, tanks, springs, and low or swampy lands where water probably could be developed. The map also shows the location of old slash, timber-sale areas, planting projects, heavy timber stands, and other areas which should receive fire protection even at the expense of the adjoining unimportant areas. Contours are indicated not only by the usual contour lines but by color or crosshatching on alternate 100-foot differences in elevation, so that a single glance will show the various slopes and topographic conditions surrounding the fire in the threatened area. This map also shows the location of fire-fighting tool boxes and equipment, and any other useful data that would naturally suggest itself to the officer in charge.

MODIFIED FORM OF RANGE FINDER.

In addition to the simple wire-cage finder, a portable instrument for range finding has been designed. The base of this instrument is set off into 180 divisions, 2° apart, instead of the 144 vertical wires in the first-described apparatus. This gives a somewhat finer subdivision of the field, and it has the further advantage of a mounted telescope with powerful lens, which will result in a better determination of the location and size of the fire. In some instances, even, it might contribute to the identification of an incendiary. On top of the telescope barrel there are front and rear sights similar to those of a rifle; these are to be used when it is too smoky or dark for use of lens.

There is a pointer in line with the long axis of the telescope, and this registers in numbered indentations on the base of the supporting plate. When a fire is sighted the telescope is focused upon it, and the number read at the pointer corresponds to a deflection line on the base map of the forest. As with the wire finder, the intersection of these lines can be determined by the next nearest signalman making a similar reading. The base plate has spirit tubes and leveling screws so that it may be adjusted to any surface and brought to a level.

This base plate enables the apparatus to be set up on any form of tower or, indeed, on a mountain top where there is no tower, provided there is an unobstructed view on all sides. In such a case it is sufficient to have a rough foundation slightly elevated by logs notched together in the shape of a pen supporting a flattened log upon which the instrument may be fastened by lag screws. In many cases the top of a tall tree could be sawed off, a scaffold erected on it, and guy wires attached to prevent swaying from wind. Other improvised devices will suggest themselves to forest officers.

Where it is necessary to erect towers for this apparatus, light windmill towers, without superstructure, would be sufficient. Such towers are very small and light, and come in detached sections which could

be packed to the tower site without having to construct special roads and trails. The sites of the towers must be predetermined, and triangulation maps made to conform to these sites. The cost of the windmill towers is approximately $30 to $50 f. o. b. at points of manufacture, such as St. Louis and Kansas City.

The approximate cost of the range-finding instrument complete is $75; allowing $40 for the tower, $10 for transportation, and $25 for installation, the total cost is only $150. With this apparatus it is not necessary to orient the tower or foundation to conform to the public land surveys, since the instrument itself can be shifted.

This range finder is suitable for cheap and improvised installation, and the telescope gives it sufficient accuracy. Yet, where an established and efficient protection is desired, the permanent towers described for the first range finder should be constructed. This is especially true, because the permanent tower provides living quarters for the watchman, and the sighting hood protects him from the weather.[1]

The ranger in charge of a district should, during the fire season, keep in touch with the telephone or in sight of the signal station, where a large flag is displayed as a fire signal by day and a red light by night. He should carry with him at all times copies of the three maps and a small lineman's sounder and transmitter, so he may cut in on the nearest telephone line when the fire signal is seen.

In many instances, and especially for larger fires, it is the best plan for the officer in charge to take his station in a signal tower and direct the fight from that point. Actual practice in the Army has demonstrated that a light, insulated copper wire may be tied into a telephone line and strung out on the brush and ground several miles in a very short time by a man on horseback. If he has an efficient representative at the fire, the officer in charge with this equipment, supplemented by heliograph, flag, and flash signals, can direct the fight more efficiently than if he is on the ground, confused by smoke and tempted to assist in the small details of fire fighting. His time could be more profitably employed in general supervision, issuing instructions, ordering supplies, employing additional men, and seeing the whole progress and course of the fight.

METHODS OF FIRE FIGHTING.

The tactics and maneuvers in fighting forest fires are not unlike those of an army in battle.

[1] The Forest Service issues protractors 5, 9, 18, and 24 inches in diameter upon both transparent and opaque paper. These protractors, in the hands of persons skilled in surveying, and used in connection with slight aledade which may be trained upon smoke previously located by binoculars and afterwards examined by high-power prismatic glass, and using the protractor for platting the intersection from a corresponding station on a map of the forest prepared to uniform scale, will give accurate results.

In its earlier stages a fire usually covers a circular area, or, if driven by wind, it assumes the form of an ellipse, or rather an oval, with the smaller end toward the point where it started.

DIRECT ATTACK.

In a fight on such a fire the force should proceed to this small end, the point that is burning slowly against the wind. There the line of fire should be cut in two and the force divided, each force to make a vigorous attack on each flank of the fire line. Under ordinary conditions the two attacking parties will follow up the blaze, and soon approach each other, and together extinguish the head of the fire which is driven before the prevailing winds.

LINES OF DEFENSE.

Defensive methods have to be varied to fit local conditions. Primarily, however, they consist of properly located fire lines. Here, again, fire defenses closely resemble military defenses. If the fire is not extinguished at once and breaks over the first line it is confronted, in its weakened condition, by the second, where a few men with improved apparatus can check the advance of even the fiercest fire by direct attack or by back firing.

Permanent lines of defense are much more dependable than mere offensive attacks, and back fires are more likely to be successful than a following fight, particularly against fiercely burning fires. However, they should never be resorted to when the following attack will suffice. It is undoubtedly a serious mistake to resort to back firing too soon, since much damage is caused by back fires, especially through the loss caused by the intense heat where the back fire and head fire meet.

Through the use of chemical apparatus, devised for the Arkansas Forest, a new plan of defensive back firing is far better than the old one of tediously raking a path through the woods at the expense of much time and labor and then going back over the ground and firing to the windward. In the old way, not only does the fire frequently break over a narrow, hastily constructed line, but even when there is no such loss the back fire sacrifices a large strip of timber between it and the oncoming head fire. With a fire-fighting force equipped with extinguishers and water bags, the back firing becomes strip firing, rapidly set by a man going ahead with a lard-oil brush-burner torch, and followed by a crew to extinguish the fire on the leeward side, leaving a single line of fire but a short distance in front of the head fire.

Other defensive methods include the construction of trails and minor fire lines, on a traversable grade if possible, connecting the major lines and the nearest water.

For use with chemical apparatus there should be metallic covered boxes, set well off the ground by stone piers, and built of suitable size to contain the ordinary fire tools and chemical extinguishers with their supply of carbonate of soda and sulphuric acid.

Where water is scarce, it should be developed in cooperation with stockmen and other forest users. This may be done cheaply by puddled earth dams across ravines of minor upper watersheds where there is abundant snowfall.

FIG. 2.—Chemical apparatus for shoulder use.

Any system of defensive improvements should be cared for by signal-tower men and forest officers at times when the weather conditions eliminate fire risk. All forest officers should devote a certain amount of their time to initiating methods and devising special apparatus to prevent and control fires.

SPECIAL APPARATUS.

It was found on the Arkansas Forest that merely the quick and accurate location of fires, in conjunction with the old methods of fire fighting, with pine tops, wet gunny sacks, and shovels did not by any means suffice for fire control. Therefore the next step was to secure special fire-fighting apparatus. These were of three general types: (1) Water bag and metallic tanks for horseback and shoulder support, depending upon gravity and sprinkle nozzles for extinguishing fires with water; (2) chemical apparatus for horseback and shoulder support, depending upon carbonic-acid gas pressure for precipitating the alkaline water upon the fire through a straight nozzle with great force and at some distance; (3) a chemical apparatus for horseback and shoulder support, equipped with a specially

FIG. 1.—BEATING OUT A FIRE WITH GREEN BOUGHS AND USING WATER IN A COLLAPSIBLE CANVAS PAIL.

[The method is slow, laborious, and wasteful of water; moreover, the strokes of the beaters sometimes serve to scatter the fire.]

FIG. 2.—FIRE-FIGHTING CREW EQUIPPED WITH WATER BUCKETS, FIRE-SHIELDS, SHOULDER-PACK WATER-BAG, AND TWO TYPES OF HORSE-PACK WATER-BAGS.

FIG. 1.—FOREST OFFICER SIGNALING WITH LANTERNS FROM THE TOP OF AN UNFINISHED LOOKOUT TOWER.

FIG. 2.—FOREST OFFICER WITH COMPLETE FIRE-FIGHTING OUTFIT, INCLUDING HORSE AND SHOULDER-PACK WATER-BAGS.

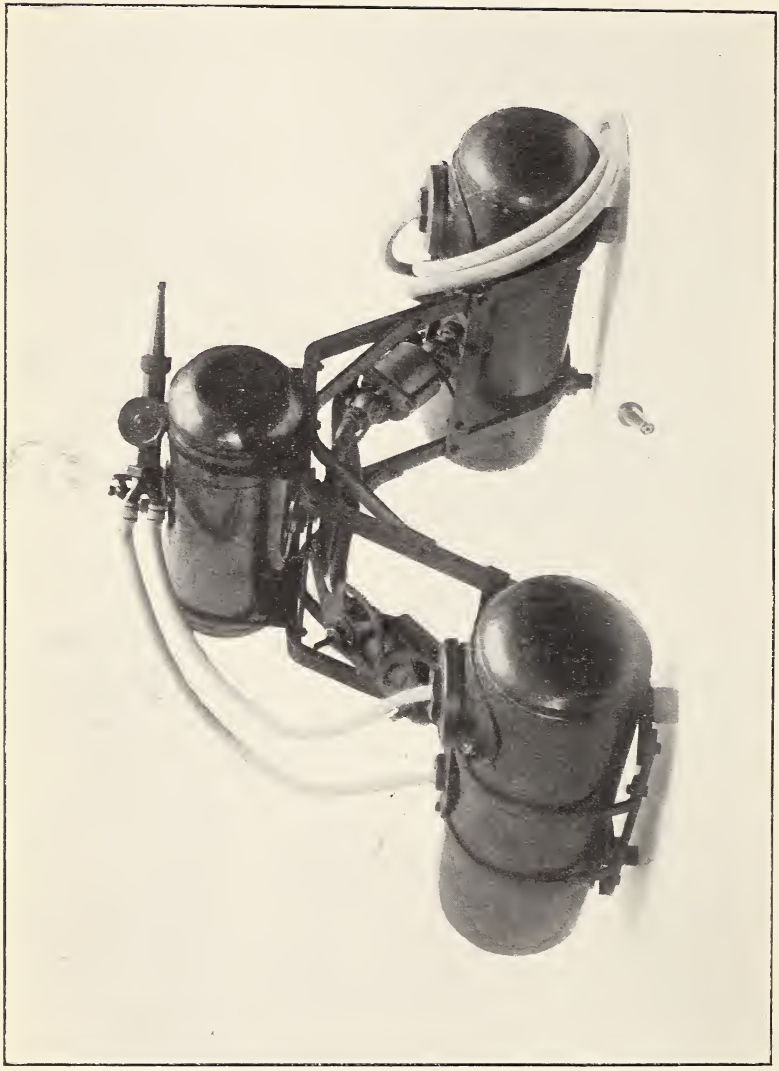
[Ordinarily a canvas water pail would be fastened over the end of the pack back of the saddle; it has been removed to show that the apparatus can be rolled into a small space.]

FIG. 3.—FIRE-ENGINE HOUSE AT WOMBLE, ARK.

[The water tanks are kept full and the harness is so arranged that the pack needs only to be dropped into place, and the straps fastened.]

FIG. 1.—WATER-PRESSURE TANKS USED IN PUTTING OUT A FIRE BURNING HIGH IN A DEAD STUB. OFFICERS MAKING A TEST OF EFFICIENCY.

FIG. 2.—FOREST OFFICER USING SHOULDER-PACK WATER-BAG AND FIRE-SHIELD IN PUTTING OUT A SMALL SURFACE FIRE.



Chemical Apparatus for Use on Horseback, with Automatic Mixing Valve and Rotary Nozzle.

designed automatic recharging device and a mixing valve and rotary nozzle to atomize the alkaline water and mix it with CO_2.

WATER BAGS AND TANKS.

The water-bag equipment was found very efficient, particularly for brisk surface fires. It is best to have a horse carry the water to the fire, and there transfer it to the shoulder-pack apparatus, since the application can be much more successfully made in this manner.

A crew of two men with two horses can carry enough water at one trip to extinguish half a mile or more of surface fire. In the actual fighting the two horses are in charge of one man, while the other man with shoulder pack extinguishes the fire.

There is an opening back of the saddle of the horse pack with a collapsible leather funnel for refilling. With this arrangement the firemen can mount and ride rapidly back to the main supply for more water. The bags hold 30 gallons—15 gallons on each side of the horse.

The whole outfit can be rolled into a compact bundle behind the saddle, and it weighs only 26½ pounds. It should be carried on field trips by all forest officers during the fire season. It consists of one horse-pack water bag, one shoulder-pack water bag, two pieces rawhide belt lacing, a bunch of waxed shoe thread and harness needle, an alligator wrench, two leather funnels, and a regulation canvas water bucket to be pulled over each end of the roll. The cost of the complete outfit is about $30.

It developed, in the use of the horse-pack water bags, that horses with well-distributed loads could be led over exceedingly rough ground, and that they were not afraid of fire. In fact, in the upper coves and upper slopes, where the fires burn with the greatest intensity, it is found practicable to use a horse-pack apparatus right at the fire. On the higher and more precipitous slopes the fires are not so fierce because of the lighter forest cover and consequent less litter; these areas can be controlled by the shoulder-pack water bag and shoulder-pack chemical apparatus, supplemented by the old method of back-firing and beating the fire out with pine tops and shoveling dirt upon it, since on the heights water is necessarily scarce.

The shoulder-pack equipment may hold from 8 to 12 gallons and has an opening at the top with wooden mouthpiece and leather funnel for filling and is equipped with a short hose and sprinkling nozzle for the application of water.

FIRE SHIELDS.

An asbestos fire shield is found very helpful, particularly with the shoulder-pack water bag, since it permits the fireman to work close to the flame and to apply the water effectively without great dis-

comfort or real injury to the eyes. This shield has a small aperture near the upper end glazed over with a piece of mica, which allows the fireman to note the progress of his efforts. The shield is made in detachable sections, which are carried under the saddle housings.

CHEMICAL EXTINGUISHERS.

The ordinary chemical extinguisher, however efficient in house fires, falls short of the requirements for forest fires. It discharges its contents too quickly to be of any practical use in the extended and scattered fires of the woods. It is unwieldy, and when accidentally inverted the chemical action sets up prematurely; nor can it be refilled rapidly enough. To meet these objections, a new shoulder-pack chemical equipment was devised.

With this apparatus, when the fireman finds it is necessary to use only a small amount of gas-impregnated water, he can slightly rotate the valve and bring into contact a partial opening to the water conduit and a full opening of gas, and may vary the relations between these openings to secure just the mixture that the occasion demands. If it is necessary to use water or gas alone, it is obvious that this can be done. In fact, this apparatus grew out of the need for economizing water. Carbonic-acid gas alone is extremely antagonistic to fire, and with the rotating valve and double-hose arrangement, the ranger can economize the water supply by fighting the fire with gas alone until the gas is very nearly exhausted. He can then use a smaller or greater proportion of water at his pleasure, and finally, when the pressure has fallen below its efficiency for gas application, he can supply the remaining water, slightly impregnated with gas. Or he may recharge the water by a small addition of the alkaline solution and acid, thereby reenergizing the entire charge and obtaining a further economy of water.

By a series of tests it was found that the time of discharge from this device was from one to three minutes longer than that from the ordinary apparatus, and the amount of water used was decreased from 3 to 1½ gallons. It is thought that the economy of water will be at least 200 per cent and the efficiency over an ordinary chemical apparatus more than 100 per cent.

An air-pressure apparatus is mechanically successful but too expensive of water. Therefore, it is not recommended for direct application of water, but for a supply tank for the horse-pack chemical apparatus.

RAILWAY FIRE ENGINES.

While no railway vehicle for fire fighting has been constructed, such an engine would be of undoubted value to follow coal-burning engines on heavy grades through the National Forests. The chemical fire-fighting car suggested in figures 3, 4, and 5 can be worked out

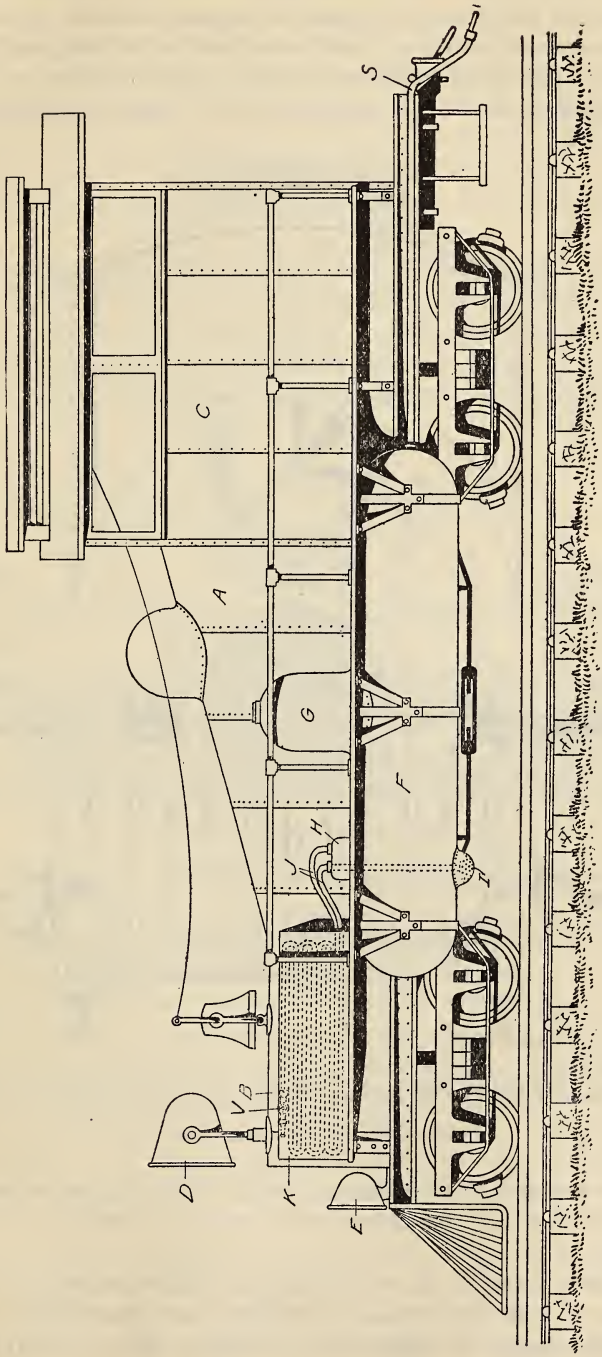


FIG. 3.—Side view of gasoline-propelled fire-fighting engine.

on mechanical lines that will insure its success. Figure 3 shows an elevation of a 120-horsepower gasoline engine installed on locomotive-like trucks, constructed of sheet steel and other fireproof material. This power should be sufficient to carry a crew of firemen with portable equipment, tools, and supplies, and to haul a trailer (shown in

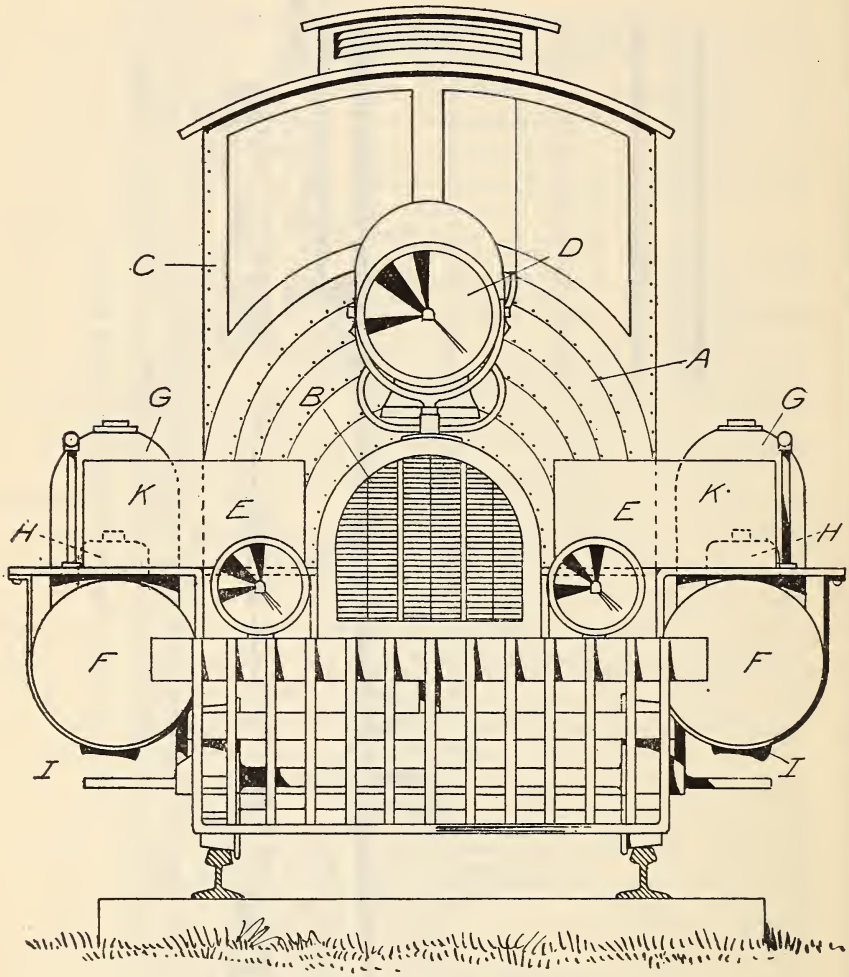


FIG. 4.—End view of railroad fire engine.

fig. 5) at a speed of 60 miles an hour. Such a speed would enable the engine to follow up-grade trains and not interfere with regular schedules.

In figures 3 and 4, *A* is a tank for alkaline solution, *B* radiator to motor, *C* cab windows, *D* headlight and searchlight combined, *EE* colored lights to differentiate machine from ordinary locomo-

tives at night, *FF* 40-gallon chemical-mixing cylinders or tanks, *GG* housing for acid tanks and automatic measuring device.

Figure 3 presents a side view of the chemical engine. *F* is a side view of the high-pressure chemical-mixing tank, and *I* an interior pipe with strainer for the discharge of solution through hose *J*. *H* is a gas dome to which hose *J* is fastened for the purpose of conveying gas into the rotary nozzle and mixing valve *V*. *G* is the acid tank and housing, which also incloses an automatic self-charging device.

The trailer is a supply reservoir and corresponds to the tender of a locomotive. The tank *M* is supplied by gravity from reservoir *L* through a check valve designed to resist compressed-air pressure from the air cylinder *R*, connected by interior piping to the header *N*. This is to force the alkaline solution forward to the mixing tank by

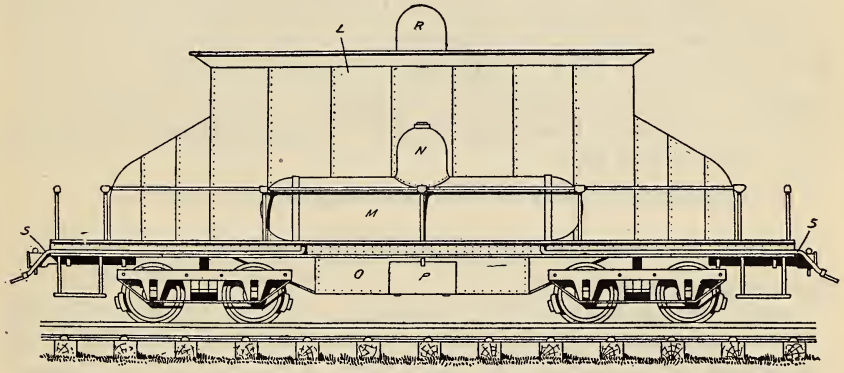


FIG. 5.—Trailer for railroad fire engine.

hose connection *S* to the high-pressure chemical engine on the motor-driven car. (Fig. 3.)

The capacity of the car and tank is 1,200 gallons; they can be refilled by suction pump from streams or from tanks.

It is estimated that this car and trailer can be built for $2,500. When it is used on railroads traversing National Forests at least one-half the cost should be paid by the railway companies under a cooperative agreement, in consideration of the lessening of their liabilities for fire damages and the furnishing of a safeguard to their own property. It seems reasonable also that the companies in cooperation should bear at least one-half of the expense of manning the car.

This equipment ought to be particularly efficient, not only in extinguishing fires in their incipiency, but in taking care of track and trestles so that trains carrying refugees to safety or supplies to burned districts might not be cut off in the burning forests.

TESTS OF TOWERS AND APPARATUS.

The five range-finding signal stations which were erected in 1910 proved so efficient that 10 more were erected in 1911–12 on the Arkansas Forest. On the Ozark National Forest there are in course of construction a sufficient number of range finders to protect the Forest.

In order to test in a practical way the combined values of the range-finding signal stations and the simple water-pack fire-fighting apparatus, a study was made on the Arkansas National Forest, where there are five stations. The control from these affords protection to more than half of the entire Forest. Horse-pack and shoulder-pack water bags were distributed equally between the rangers on the area protected by watch towers and those on the unprotected areas, to afford an impartial working basis. All five of the signal stations were not installed in time to keep a full record for the first half of the fire season, which, in Arkansas, is in the winter and extends from October 1 to May 1. However, a record was kept of the fire damage on the two areas up to January 1, and the difference in favor of the protected zone was $11,560. From January 1 to July 1 a close record was kept.

The following is a copy of the official report:

Fire report Jan. 1, 1911, to July 1, 1911.

Total number of fires:

North (unprotected)	16
South (protected)	20

Area burned over:

	Acres
North (unprotected)	109,514
South (protected)	14,267

	Damage.					Cost.		
	Thousand board feet.	Value.	Reproduction.	Forage.	Total.	Temporary labor.	Rangers' labor.	Total.
North (unprotected)	6,904	$17,274.00	$19,553.00	$20,522.00	$57,349.00	$166.39	$110.22	$276.61
South (protected)	717	721.00	9,295.00	9,902.00	19,918.00	126.90	140.50	267.40

SAVING DUE TO IMPROVED METHODS.

The comparatively high figures under "Forage" include the estimated damage to the humus. The total difference between the unprotected and protected areas amounts to $37,440.21. Adding to this the $11,560 for a portion of first half of season, we have a net gain, as between the two areas, of $49,000.21.

When we consider that this saving represents that from only one-half of a single one of the 159 National Forests in the United States, the magnitude of the possible results may be appreciated. Moreover, it is fair to assume that if the unprotected area of this forest had not been supplied with water bags, and if the protected area had been supplied not only with range finder and water-bag equipment, but also with a complete equipment of chemical fire-fighting apparatus, the comparative gain would have been at least twice as great.

One of the strongest advantages of the range-finder system is the effect it has on persons otherwise given to incendiarism. The incendiary fully realizes that he is, in a way, being watched, since the first smoke from a fire is immediately reported to forest officers, who hurry to the scene; and the trespasser naturally fears quick arrest. This point is clearly brought out in the preceding report. While there were 20 fires on the protected area against 16 on the unprotected, the protected area previous to the installation of lookout towers was a veritable hotbed of incendiarism, and fires were so numerous and frequent that they practically burned over the entire south half of the area and a portion of the north half every season.

A NEW SYSTEM OF LOGGING AND FIRE LINES.

It is very important, especially on areas that are being lumbered, that a comprehensive system of fire protection and management of lumbering be inaugurated. Figure 6 illustrates a typical National Forest sale area surrounded by two spurs that join the main divide. The area is drained by a large creek and numerous smaller tributaries. The logging road is projected along the main creek, with various branch spurs to remove the timber from the minor watersheds.

The major fire line should be constructed entirely around the area below the ridge before logging operations begin. This line is intersected by minor fire lines which follow the interior ridges and separate the area into seven logging units.

Ordinarily logging operations are commenced near the mill and the timber is removed in successive steps as the logging road is built up the draws. Experience has demonstrated that this method is to blame for many serious fires, since the slash and brush piles next to the mill become dry and are almost sure to catch fire from engine sparks or from the carelessness of logging crews passing and repassing the cut-over area while removing the timber from successively more distant portions of the area.

To avoid this risk the lumber operator should first construct the main line for his logging road from the mill practically to the limits of the operations (shown in the figure at X). The uppermost spur lines (B and C) would then be constructed and the timber removed

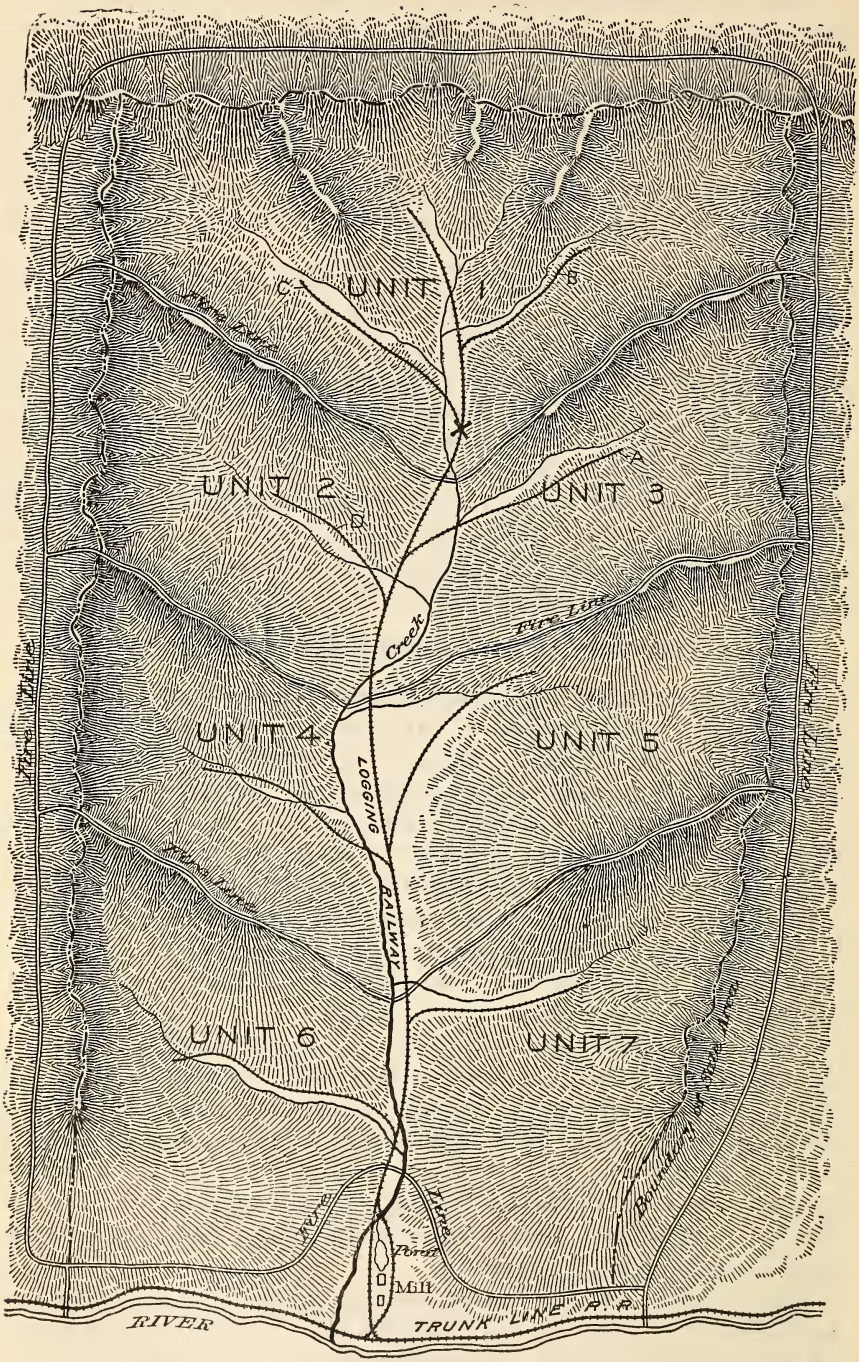


FIG. 6.—A typical lumbering area, to illustrate a new system of logging and fire lines.

from the first unit. After this has been done the upper spur tracks should be removed and laid on the tie beds, in next lower units (at *A* and *D*), which in the meantime had been graded. The timber is cut from the units served by these tracks, and the area closed in turn.

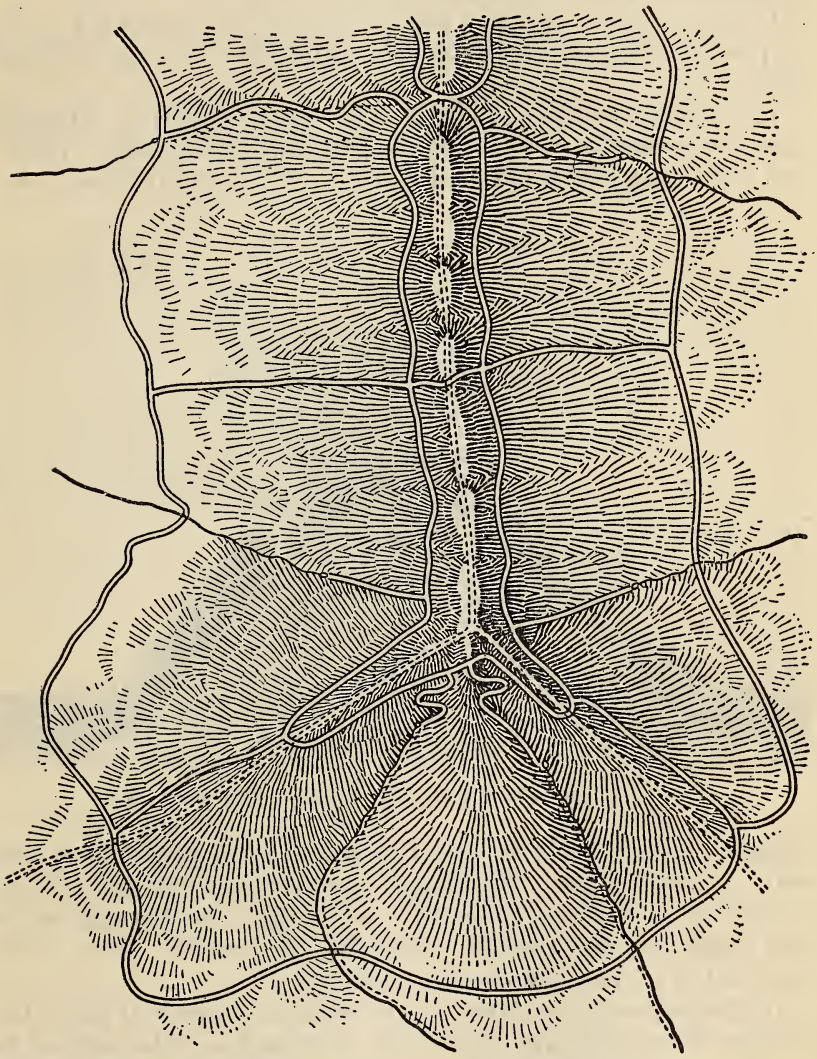


FIG. 7.—A new location for fire lines; the dotted lines show the old location at the tops of ridges.

The rails (from *A* and *B*) are then relaid (for units 4 and 5), and the operation continued until the entire area is logged. In the meantime, if fire breaks out on any unit which has been logged, it can be restricted to one unit by the help of the fire lines which separate the units.

In the construction of these temporary lines on the Arkansas National Forest the work was done very cheaply by felling the dead timber near the line, particularly on the outside, raking and burning a strip from 40 to 60 feet wide on the ridge lines, and cutting and rolling clear of the line all dead and down timber.

Irrespective of logging, a new location is proposed for fire lines in place of the generally accepted position on the crests of ridges. (Fig. 7.)

It is well known that wind has a horizontal direction. However, when obstructed by a mountain, it conforms to the slope. When a fire is burning, by reason of differences in density of heated air, a

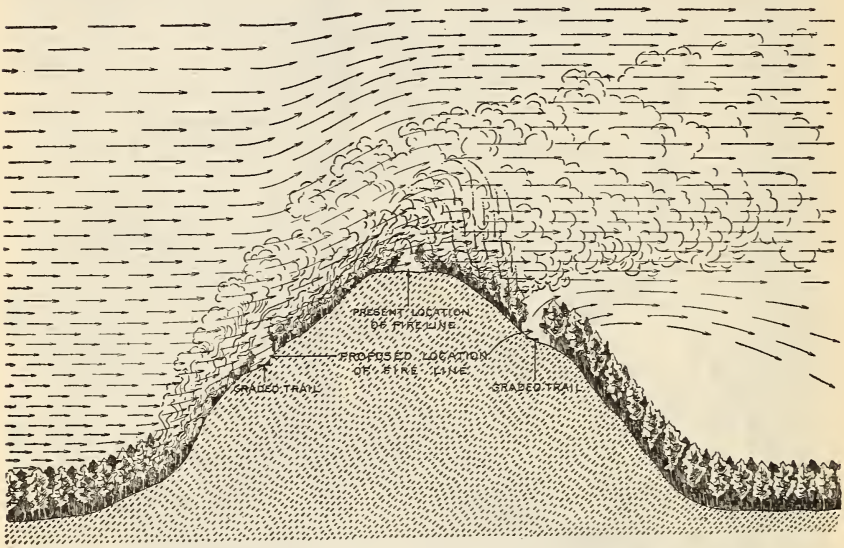


FIG. 8.—Effect of the new location for fire lines.

strong undercurrent is set up which has a rapid ascending velocity with a spiral motion. This motion, together with the natural wind velocity when the fire reaches the crest, projects the burning embers and sparks far over the top. Therefore, the present system of fire lines on top of the ridge seems inefficient.

In the proposed plan, however, the burning embers will fall within two fire lines, which are placed well under and on either side of the mountain top. (Fig. 8.) It can be reasonably expected that an ordinary surface or light crown fire can be held at the first line; however, if the fire does break over, the second fire line, under the new system, furnishes a basis for back firing and fighting the more slowly burning, descending flames with the improved apparatus.

Furthermore, there are strong arguments against the location of the fire lines on crests: First, the cover on top of the ridges should not be disturbed; second, the fire lines on the very backbone of the mountain usually can not be utilized as trails, because of the rough and irregular profile of the ridge line. It is entirely feasible, on the other hand, to locate and grade the fire lines approximately along contours, so that they will serve for patrol and for the transportation of supplies and equipment. However, this plan of double-line location is not intended to apply to ridges with crowns so level that they are practically smooth and easily graded.

ADDITIONAL COPIES of this publication may be procured from the SUPERINTENDENT OF DOCUMENTS, Government Printing Office, Washington, D. C., at 10 cents per copy